Study of two edge detectors attending to their robustness with respect to speckle noise in SAR images

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Abstract- A comparative study of two edge detectors attending to their robustness with respect to speckle noise is presented. The Canny edge detector and the CFAR detector proposed by Touzi et. al are compared. A coastal SAR image acquired by TerraSAR-X is used. The Canny detector is a reference method in image processing. In this work, it is combined with the Lee and the Mean-Shift filter, which has been proved to outperform the Lee filter. The CFAR detector is applied to the original SAR image. Attending to coastal line detection and the preservation of small islands present in the image, the CFAR detector performs better than the Canny one with the Mean-Shift filter. Results show that the use of higher values of probability of false alarm gives rise to very good results with smaller windows, avoiding the application of further techniques for thinning the detected edges.

I. INTRODUCTION

Synthetic Aperture Radars (SAR) produce high resolution remote sensing imagery using antennas installed aboard mobile platforms, as aircrafts or spacecrafts. A main application deals with the mapping of terrain and sea surfaces to detect and classify point and extended targets.

After compression, one of the problems to take into consideration in the processing of the formed image is the speckle noise. This noise is due to the coherent sum of many elementary scatterers in each resolution cell and gives a grainy appearance to images that makes detection and classification tasks more complex [1]. Mean and medium filters, other adaptive techniques as Lee [2], Kuan [3] or Frost [4] filters, and new versions of them [5], have been proposed. Also, wavelet-based algorithms have been applied successfully [6,7].

Mean-shift (MS) is widely applied in pattern recognition tasks and many image edge preservation filtering and segmentation applications are based on it [8-10]. MS filtering was introduced in SAR imagery by Cellier et al. [11] for shadow extraction and building reconstruction, from the amplitude and coherence images acquired by RAMSES, an interferometric French SAR airborne sensor (ONERA, Boutry 1998). In [12] a study of mean-shift performance attending to speckle noise reduction was carried out using images acquired by Envisat’s ASAR (ESA). Results proved that MS can improve on the Lee filter in speckle noise reduction and textures and edges preservation.

In [13] the problem of edge detection in SAR images was considered and MS a Lee filters suitability was evaluated attending to the outputs of a Canny edge detector and a segmentation stage, with the objective of detecting coastlines and obtaining a land mask. Results prove that the combined spatial-range processing make MS more suitable.

In this work, the problem of coastal line detection is revisited. Taking as a starting point the results obtained in [13], two edge detectors are compared: the Canny algorithm [14], which is a reference in image edge detection tasks, and the Constant-False-Alarm-Rate (CFAR) detector proposed by Touzi, Lopes and Bousquet [15]. This CFAR detector considers the multiplicative model of speckle noise and is presented as a very robust technique with respect to this noise. The Canny detector will be applied to the images previously filtered using the Lee and the MS filters, to evaluate its dependence on speckle noise. The CFAR detector will be applied directly to the original SAR image.

II. RESULTS

A stripmap detected image acquired by TerraSAR-X (DLR) is considered, with the following characteristics [16]:

- Product type: “GEC”/”RE”
- Polarization: single HH
- Resolution: 6.97m x 6.78m.
- Effective number of looks: 6.1

Results obtained from a zoomed area of this image (Fig.1) are presented in this section. It has been selected because of the presence of small islands close to the coastline and a high level of speckle in sea and land areas, that complicates the edge detection task.

Firstly, as in [13], the performance of the Canny edge detector has been analyzed for two speckle filtering techniques: the Lee filter and MS. In Fig.2, the following cases have been considered: Canny detector applied directly to the original image (Fig.2.a), Canny detector applied to the image filtered using a Lee filter with a 5x5 window (Fig.2.b.), and Canny detector applied to an image filtered using MS after being transformed by a logarithmic function (Fig.2.c). When the Canny detector is applied to filtered images, the thresholds can be increased, reducing the number of non significant edges detected in land areas. In Fig. 2.a. most of the islands are preserved, but too many not
significant edges are detected in land, given rise to a high $P_{fa}$ in edge detection. Using a previous filtering stage, the number of edges detected in land reduces significantly, but some of the islands are lost. Results show that MS provides better results as a compromise between land edges and detected islands.

In Fig. 3, the results obtained applying the CFAR detector directly to the original signal are presented. In Fig. 3.a and 3.b, for a $P_{fa}=0.05\%$, the edges detected for two windowing stages are presented: in Fig. 3.a, a 3x3 window is applied and in Fig. 3.b the edges detected using a 3x3 window and a 5x5 window are superimposed. In the last case, more edge details are obtained, at the expense of increasing their thickness and their visual impact. Fig. 3.c has been obtained for $P_{fa}=0.1\%$ and a 3x3 window. Comparing Figs. 3.a and 3.c, we can conclude that when $P_{fa}$ is increased, the detected edges are clearer. Although, the $P_{fa}$ increase gives rise to a higher number of non significant detected edges, due to the use of a small window, they are thinner and their visual impact is less than in Fig. 3.b.

### III. CONCLUSIONS

A comparative study of two edge detectors, the Canny one and the CFAR detector proposed in [15], has been carried out, attending to their robustness with respect to speckle noise. The Canny detector performance has been evaluated in three cases: with no speckle filtering, using the Lee filter and using the MS filter. Taking into consideration the design of the CFAR edge detector, it has been applied directly to the original speckled image.

A coastal detected image acquired by TerraSAR-X has been used, because of the presence of a significant speckle noise level and many small islands. Results prove that the performance of the Canny detector improves considerably when it is combined with a speckle filtering technique. The results obtained using the MS filter are better than those obtained using the Lee filter. MS combined spatial-range processing allows to over-smooth land and sea areas using high values of spatial bandwidth, and preserving the coast line and the islands using very low values of range bandwidth. When the Lee filter is used, big windows can smooth sea a land, but without preserving clear edges.

Despite the CFAR detector is applied directly to the original speckled signal, this detector improves on the best results obtained with the Canny detector combined with a speckle filter. The non significant edges detected by the Canny algorithm define regions in land, while those detected by the CFAR one are point like, and could be reduced easier in a posterior processing stage.

### REFERENCES


Fig. 1. Zoomed area of the mouth of the Mississippi river.
Fig. 2. Results obtained with the Canny edge detector: a) Without speckle filter and Canny threshold 0.25, b) Lee filter with 5x5 window and Canny threshold 0.4, c) Logarithmic transformation, Mean-Shift with h_s=8 y h_r=0.05 and Canny threshold 0.35.

Fig. 3. Results obtained with the CFAR edge detector applied to the original image: a) Pfa=0.05% and 3x3 window, b) Pfa=0.05 and 3x3 and 5x5 windows, c) Pfa=0.1% and 3x3 window.